the receiving and distributing network of weather-reporting stations. Reports from sea, however, were scant, owing to the ban upon the use of radio.

At each observatory, when in full working order, there were two aerographic officers and six quartermasters, class A, aerographic. Commanding officers could thus call for information and advice at any hour of the day or night. Sondages at some important coast stations were taken every two hours. Many commendatory reports have been made regarding the service in connection with the operation of both lighter-than-air and heavier-than-air machines. Particularly in connection with the successful operation of blimps was the value of wind directions and velocities at different levels apparent. At some stations the number of hours of patrol increased decidedly after the establishment of the aerographic observatory. In addition to surface and flying level winds, the aerographer was expected to forecast visibility and especially advection fogs and sea fogs. Thunderstorms, gustiness, changes in the lapse rate (vertical gradient) of temperature as well as horizontal gradients, heavy rains, likelihood of snow at high levels, frosts, and surface temperature inversions were regarded as subjects bearing directly upon the safety of fliers and therefore to be noted and investigated with all diligence.

At first, American naval aerographers followed rather closely the methods of the British observers in the Hydrographic Department of the Admiralty, but in France they soon discarded the old English units and also modified materially the methods of work. Many good suggestions came from various members both in the field and at home. The two-theodolite method originally used at Blue Hill was soon displaced by the one-theodolite method of following pilot balloons, and while it is fully recognized that this method is open to criticism, it is quick and worked fairly well in actual operation. Several rapid methods of calculation were designed by the officers at Blue Hill. All of these can not be described here, but those of Ensigns Davy, Twitchell, and Mall were successfully tried out. Inasmuch as a short review of some of these methods may be of interest to others working in this field, I append a note by Ensign Mall, which, while not describing his own automatic device, gives briefly the cardinal points of the Davy Rapid Calculator and the Twitchell Vector. An extended paper on the subject has been prepared by Ensign Twitchell, but can not be given here. Ensigns Townshend, Parsons, and Davy designed an automatic balance for use in filling balloons, giving free lift and dead weight. Ensign RuKeyser designed a cage for approximately determining free lift, for use where other methods could not apply.

Some studies of the depth of the sea breeze in the East Gulf were made by Lieut. Reed at the Pensacola station.

During the absence of Prof. McAdie abroad, the following lectured to the classes: Chief Observer L. A. Wells, Ensigns Keyser, Buck, Townshend, Davy, Parsons, Mall, and RuKeyser. Lieut. R. F. Barratt was in charge of foreign stations after the return of the senior aerographic officer to the United States.

Eighteen stations were established in France, six in Ireland, and two in Italy. An account of the equipping and instrumental work in the United States is given in the following note by Commander Jewell.

WORK OF THE NAVAL OBSERVATORY IN CONNECTION WITH NAVAL AEROGRAPHY.

By Commander C. T. JEWELL, U. S. N., Retired.

[Communicated by the Superintendent, Naval Observatory, Washington, Mar. 14, 1919.]

The Naval Observatory's proper function in the development of aerography was the procurement and issue of suitable instruments. This was accomplished under the superintendency of Rear Admiral T. B. Howard, U. S. N., retired.

When the policy of establishing naval flying stations at home and abroad was definitely adopted in the summer of 1917, the Observatory, on its own iniative, added to the allowance list an aneroid barometer, a wet-and-dry-bulb psychrometer, and a masthead anemometer, all Navy standard articles of which there was a stock on hand, so that the Air Stations could keep a record of weather conditions commensurate with that kept on board vessels of the Navy.

The following winter it developed that there was need of more extensive equipment. An appeal to the Observatory was made in December, 1917, for pilot balloons and theodolites for air sounding, and in the following summer the Observatory went into the market for a full set of meteorological instruments for air stations in the United States.

A step in advance in the way of cooperation with foreign observers was made at this time by having the charts on which records were kept by recording instruments of various types printed in metric and centigrade scales rather than the usual English units.

Wind vanes were supplied without registers, for visual observation only, as it was early recognized that our business dealt with the upper air currents and not with the surface winds.

An anemometer recording the passage of air equal to a wind movement of 1/60 of a mile had been adopted for naval use before the war. These were issued to Air Stations at home. Air Stations abroad were supplied with instruments obtained abroad without any action on the part of the Observatory.

After supplying instruments recording in metric units, the pressure, temperature, and humidity at the stations on shore, the Observatory turned its attention to wind-measuring instruments. The Draper Instrument Co., of New York, supplied 20 anemoscopes of their design. These instruments show the exact direction of the wind at any moment, giving a record which illustrates the variability of the wind as well as its general direction. For wind pressure and velocity, the department finally adopted a modification of Dine's anemobiagraph.

The development of the Aerographic Service at the home stations is practically the work of Ensign E. B. Buck, U. S. N. R. F. First he had charge of the aerographic students at the Blue Hill Observatory; later as an assistant to the Director of Naval Aviation, he advised as to the detail and station of the aerographic officers he had trained, and finally, as an assistant to the superintendent of the Naval Observatory, he handled the minutiæ of getting the home stations equipped and operations started. Key West, Miami, Chatham, Halifax, and San Diego were actually at work keeping records and making forecasts at the time the armistice was signed. Bay Shore had been equipped, but never operated. Halifax and Chatham were supplied at this time with equipment for pilot-balloon work, and five complete outfits for France were on the wharf awaiting transportation.

In addition to the Air Stations above named, Brunswick, Ga., and Hampton Roads, Va., have since been put on an operating basis. Rockaway Beach, Long Island, N. Y., has also been equipped. Several of our stations are now regularly cooperating with the Weather Bureau, sending in daily reports of conditions in the upper air and receiving regular forecasts. At nearly all the patrol and flying stations, commanding and flight officers are kept informed constantly of the force and direction of the wind at flying levels and of the weather to be expected during practice hours.[1]

For more than a year the Observatory has been working to secure a suitable recording instrument for measuring meteorological conditions in the upper air while carried by a seaplane in flight. Two forms of instruments for this purpose are now nearing completion. Their perfection will complete the instrumental outfit for Naval Aerography.

[1] See map p. 209 for location of the naval aerological stations.

METEOROLOGY IN THE NAVAL AVIATION SERVICE OVERSEAS.

RUY H. FINCH, U. S. N. R. F.

[Dated: Weather Bureau, Washington, Feb. 14, 1919.]

Aside from bombing a few ports held by the Central Powers and some convoying of ships, the work of naval aviation was primarily hunting submarines. Hence forecasts and data were mainly for use over the ocean.

Forecasting for the coastal waters of northwestern Europe presented many difficulties, especially to those who had been accustomed to having a broad expanse of land to the west from which reports are received showing the more or less regular progress of HIGHS and LOWS. There, too, one had to deal with a series of LOWS with only occasionally an intervening traveling HIGH. The HIGHS that most commonly affect the western coast of Europe—oceanic conditions—are the slowly shifting, sometimes stationary ones either of continental origin or from the Azores region. The first intimation of the approach of a storm to northwestern Europe in the absence of wireless reports from the Atlantic is from the effects due to the storm itself—the formation of cirrus and other characteristic clouds, the falling of the barometer, and the backing of the wind at the westernmost stations. This latter often seems to anticipate a fall of the barometer, but it is still a mooted question whether the backing of the wind precedes or accompanies the change from stationary, or rising, to falling barometer.

At many of the American stations it was impossible to get the British forecast, or any reports, in time to help in making the morning forecast; and one had to be guided by local conditions and by old reports. The backing of the wind and fall of the barometer would herald the approach of a storm; but, of course, only a short time before the onset. Clouds, however, gave more advance information of the coming LOW. Along the western coast of France and over the British Isles the wind circulation nearly approaches the ideal circulation found in well-defined storms over the ocean. Most of the meteorological huts were stationed along or near the coast, usually near the landing places of the seaplanes, and were excellently situated for cloud observations. By noting the appearance and direction of clouds of the cirrus level, and the time interval before the developing of alto-types, one could get a good idea of the intensity and distance away of coming storms. By noting departures from expected wind direction and cloud movements, and assigning a reason for such departures, one could often locate secondary depressions, even when they were passing to the south of the observer. When low clouds prevented good cloud observations one had to be guided by the wind direction and the barometer. In many cases elaborate cloud observations were unnecessary, for short-range forecasts—6, 12, and 24 hours—were all that were desired.

Synoptic charts were drawn, and, though usually too late to be used in making morning forecasts, they gave a good check on the interpretation from local conditions, and aided one in studying the causes and effects of weather happenings. In cases where synoptic charts were available in making forecasts they were used only in conjunction with local conditions. Land-and-sea-breeze conditions occasionally afforded easy forecasting of wind velocity and direction.[1]

Forecasts included wind velocity and direction from the surface up to 2,000 or 3,000 feet, weather (rain or fair), height of clouds if low, and visibility. At stations where dirigibles were used forecasts had to be more definite and a closer watch kept of the weather than at seaplane stations.

Visibility is of prime importance in hunting submarines from aeroplanes. A haze that would permit of fair discernment of large objects would completely obscure a periscope or a submarine slightly submerged. The forecast of visibility was for the distance in miles at which selected objects could be clearly seen. Colored glasses for observing through haze were used with some success. By noting the causes of poor visibility, and by correlating visibility at sea with the visibility and general conditions near the meterological hut, one could make good forecasts of the visibility seaward. Although a qualified observer, it was mainly for visibility correlations that the writer went up on a patrol as observer.

The British forecasts always included the gradient velocity, which was assumed to obtain at 1,500 feet. The British Admiralty, however, were inclined to take 2,000 feet as the average level at which the gradient velocity is reached. The current gradient velocity was obtained from the weather map by means of transparent scales similar to those drawn in figure 1. They were calculated for the latitude of the British Isles for use on the daily weather reports (scale 1/20,000,000) with isobars drawn for every 5 millibars. Several radii of curvature for both cyclones and anticyclones are usually given, and one or two trials will usually show the curve nearest the required isobar. Then, by noticing where the next isobar crosses the scale, the wind velocity is read off. From theoretical considerations of the decrease of density and the pressure gradient with increase of elevation tables have been computed giving velocities for all elevations up to 30,000 feet corresponding to gradient velocities at the surface. They were but little used and are of doubtful accuracy.

[1] See discussion of forecasting in western Norway: MONTHLY WEATHER REVIEW Feb., 1919, 47: 90-95